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ABSTRACT

To aid in providing a sounder methodological program in the teaching of trumpet playing, a study was made of the profiles of physical parameters involved in playing the instrument. Data were collected while beginning, intermediate, or advanced players performed scales in F, D, and B-flat and two etudes in both staccato and legato. The means used to record the data were: audio recording of sound; graphic representation of sound; measurement of air pressure and a graphic representation of these recordings; measurement of air flow and graphic representation of these recordings; and anatomic cine X-rays of the larnyx during sound reproduction. The results are related to pressure control, absolute pressures, sound volume, and the importance of the vocal chord. Recommendations to teachers are that: (1) particular attention be given to achieving pharyngeal air pressure control in beginning students; (2) less effort needs to be given by the beginning players to achieving high pressure volume; (3) an increase in volume of air pressure will not necessarily lead to an increase of volume in the production of sound, but rather, it is through precise pressure variations and correlations between vocal chord and mouth region; and control movements of the true vocal chord are the most important for the production of sound and sound interruption in trumpet playing. (DB)

FINAL REPORT
Project No. O-H-008
Grant No. OEG-8-70-0003 (509)

The Improvement of Brass Instrument Teaching Through the Use of a Profile of the Physical Aspects Involved

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WEBER STATE COLLEGE
Ogden, Utah

May, 1971

U.S. DEPARTMENT OF
HEALTH, EDUCATION AND WELFARE

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The Improvement of Brass Instrument Teaching Through the Use of Profile of the Physical Aspects Involved

(A Method for the Establishment of
Physical Parameters in Trumpet Playing)

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INTRODUCTION

In 1967 Nichols and Hansen initiated a study to investigate the nature of the physiologic mechanisms for the control of sound production in wind instruments. Previously no precise explanation about the correlation of movements of the larnyx, of the diaphragm, the pharnyx, the tongue, the soft palate and the lips was available, although it was known that four basic control points could singly or in combination produce variations in pressure of the air column within the body and behind the lips and mouthpiece.

1. The entire muscle system of the chest wall and abdominal wall could relax and thus reduce the pressure and interrupt sound production.

2. The muscles of the larnyx are anatomically placed at a point that they could control the pressurized column a few centimeters behind the locus where air pressure exerts its finite effect at the mouthpieces and lips.

3. The muscles of the oropharnyx at the back of the mouth could interrupt the air column.

4. The tongue can thrust into the lips, thereby obstructing the air column immediately behind the lips.

Hanson and Nichols considered the possibility of all control levels and discussed the advantages and disadvantages of each possibility. By devising simultaneous recording of the trumpet sound and photographing cine X-ray pictures of the anatomical parts involved during the act of playing they established a set of basic findings:

1. In contrast to widely held assumptions about the relative contribution to each anatomic part to sound production in trumpet playing it was found that the movement of the larnyx was the prime controlling factor in sound production for trumpet playing.

2. Secondary control was accomplished by movements of the tongue and the resultant modification of the air column in the mouth.

3. No control was exercised at the level of the diaphragm.

4. Correlation of sound produced with the cine X-ray depiction of larynx and tongue was attempted and produced very suggestive results, but final conclusions were not possible on the basis of the available evidence.

The authors established the feasibility of the diverse method for a more detailed investigation and proposed a study with the following objectives: Further development of these ideas culminating in a systematic investigation of differential profiles between trumpet players of different levels of instrument mastery were proposed as basic objectives of the study on which this report is based.

Two basic objectives were projected:

1. The investigators intended to establish comprehensive and precise profiles of physical parameters in trumpet playing by recording a set of significant data simultaneously. These data would be collected from subjects while playing the instrument and would include:

   a. Audio recording of sound.

   b. Graphic representation of sound.

   c. Measurement of air pressure and graphic representation of these recordings.

   d. Measurement of air flow and graphic representation of these recordings.

   e. Anatomic cine X-rays of the larnyx during sound reproduction.

   f. Assessment of air temperature in the air column of the trumpet mouthpiece.

   The last objective was dropped from the investigation after intensive efforts to obtain accurate measure on this dimension yielded no significant results.

2. If successful measures on the above mentioned objectives could be obtained, systematic analysis of profiles from beginning, intermediate and advanced players would be conducted. Comparison of records obtained should yield insights into differences of anatomical and physiological conditions connected with performance levels which in turn could establish a reliable and verifiable basis for the instruction of trumpet players.

The investigators recognized two basic limitations of the proposed study from the outset of the investigation:

1. The sophistication of the measurement instruments needed for the study could not easily be replicated in other settings and thus probably made a large-scale application of the method to the regular music teaching setting difficult.

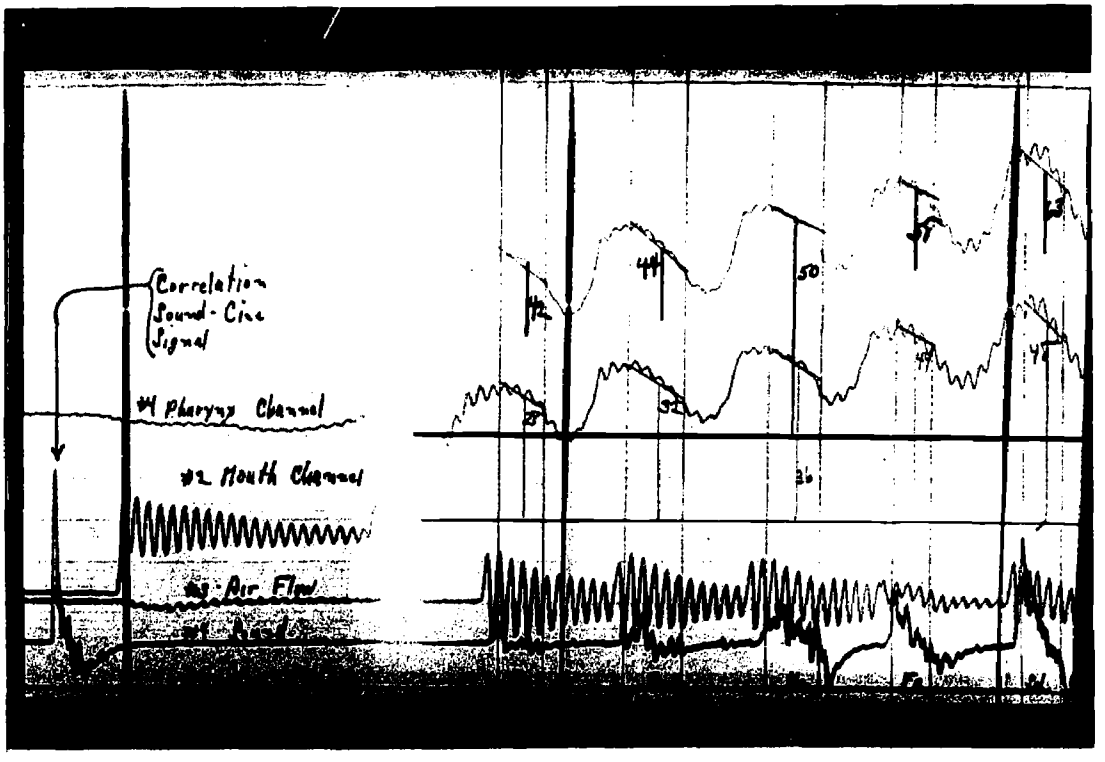
2. The technical requirements for establishment of physical parameters of trumpet playing mandated the availability of specialists competent to conduct the necessary procedures. Nevertheless, since the proposed research was unequivocally categorized as "basic research" - rather than "applied research", the investigators felt justified to proceed with the projected study.

METHODS

I. Technical features of the Study

Of major importance for the achievement of the stated objectives was the production of the technical research tools required in the project. Accordingly primary emphasis during the initial months of the project was directed toward technical design and projections of measuring devices needed for the establishment of physical parameters in trumpet playing. Technical features for individual recording were designed, tested, calibrated and used for trial runs with five players, who volunteered for this aspect of the study. Five dimensions of data recording were chosen for the accomplishment of Phase I (establishment of measuring devices) and Phase II (establishment of differential profiles). (Figure 1)

Figure 1
(Typical record - Advanced Player
D. T. ascending staccato)



a. Development of technical features.

The sound of each trumpet player was recorded with a standard monaural recorder. Correlation of the sound tape with graphic recording and with cine X-ray recording was accomplished with the aid of a clapper board. Its sound was recorded on the tape and its converging leaves were recorded in the cine X-ray studies.

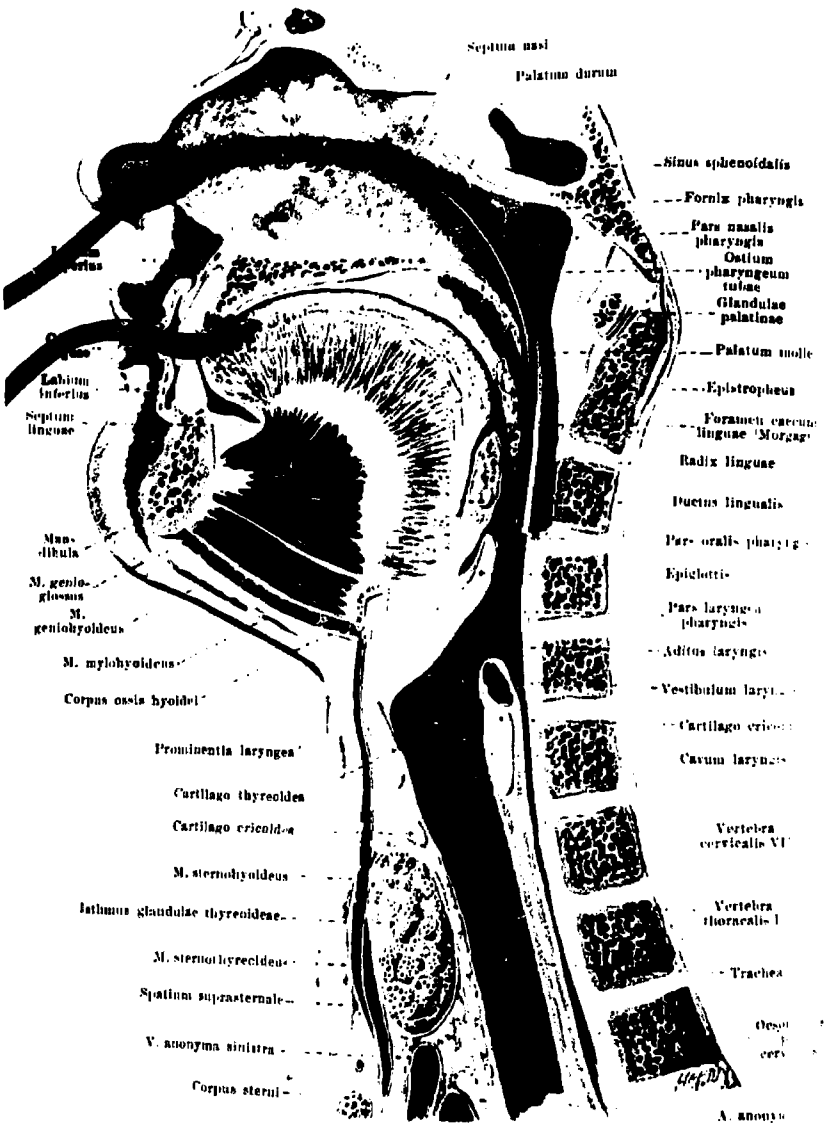
b. Graphic representation of sound.

The sound on graph was recorded via a lapel microphone. Its pickup was fed into a preamplifier unit which emphasized the bass components of the chosen piece. The obtained signal was filtered through two stages of amplification and finally transmitted to the microgalvano-meter of a model 906 Visicorder. The galvano-meter of this instrument is gauged to a characteristic frequency of only 40 cycles. While this condition reduced optimum recording of trumpet sounds slightly, it did not produce sufficiently significant deviations which might have nullified this dimension of the investigation. Indeed, graphic recording at 100 mm per second paper speed sufficied for the identification of individual notes played in short passages of trumpet music. Correlation of this graphic sound channel with cine X-ray recordings was achieved with a simple device. The sound of the clapper board was portrayed by a sharp spike which could be identified with a single specified frame of the cine X-ray recording. (See figure 1, left corner "spike" for correlation sound-cine signal).

c. Measures for air-pressure.

Two simultaneous pressure channels were constructed, Strathamstrain gauges number 238B were selected and appropriate amplification fed to the Visicorder. A calibration chain was attached to each channel. Calibration to 5, 10, and 20 millimeters of mercury were performed for each channel before and after each recording session. Recording for the first pressure channel was accomplished in the area of the hypopharynx. For this purpose a polyethelene tube of approximately 2 mm diameter was passed through the nostril of each player and anchored at the level of the upper margin of the epiglottis. (Figure 2)

Figure 2
(Anatomy of pharynx and mouth
catheters for pressure recording)



Calibration of this pressure chain did not cause great difficulties. However, during active playing of the instrument considerable air turbulence emerged in the region of the hypopharynx. This turbulence lead to temporary variations of 25% to 50% in the measured total pressure. In order to overcome erratic pressure patterns the investigators agreed on recording of average measurements, thus conceding the possibility of regression error in graphic representation of this dimension.

The second pressure channel was located at the anterior portion of the mouth cavity slightly behind the upper incisors. Some of the subjects had no difficulty in keeping this tube for the pressure channel in the appropriate place. With other players, only intermittent recording of air pressure was obtained through this channel. Several attempts were made for the correction of this problem. Slight improvement in the dependability of pressure recording in channel 2 was finally achieved through affixing the tube with the use of orthodontic resin. Air turbulence occurred similar to the one described before. Considerable variation of air pressure during the sounding of a single note convinced the investigators to apply a measurement of an average pressure with the recognized attendant possiblity of error.

d. Measure of air flow.

It was originally projected to attempt a recording of air flow in the tube of the trumpet mouthpiece. Hypothetically it was assumed that variations of air-flow may indicate significant differences between levels of competence in trumpet players, thus supporting the basic theme of the investigation that levels of accomplishment correlate with specified physical measure obtained from various dimensions of playing. Four trumpet mouthpieces were modified to contain a small metal tube (hypodermic needle of #16, #20, and #22 gauge). These were oriented in different ways within the mouthpiece and numerous trial runs were done with them. The most consistent recording were obtained with a number #20 needle which was cut off squarely and slightly flared with its tip pointing directly toward the subject's mouth. The mouthpiece was calibrated with steady measured air flow. Consistent deflections ranging from 2 to 10 liters of gas flow per minute were obtained during the calibration sequence. However, when the trumpet

was actually played during selected exercises, turbulence at this level led to such variations of deflection that concise measurement of air flow was not possible. While this dimension of the investigation did not prove to be successful the investigators are of the opinion that further research into this aspect should be conducted and suggest that some form of heated resistance wire might open more accurate possibilities for the measurement of air flow. (Figure 3)

Figure 3
(Mouth pieces prepared for flow rate determinations)

e. Cine X-ray of Anatomical Details.

Cine X-ray recording of the larnyx in AP and lateral projections on tongue, palate and oro-pharynx were obtained with the use of a Philipps Cine pulse unit powered by three-phase 1000 MA supply. Original Cine runs were produced at 25 frames per second with 5 ms filming pulse at distance of 40 inches without grid. Analysis of these original films indicated that a player frequently would hold a single note for only 2-4 film frames and intervening rest for 1-3 frames. In order to correct this condition and to achieve better standardization a fixed 8 to 1 grid with 32 inch to 42 inch focal distance was added to the unit and films at 50 frames per second were made in subsequent trials. Evaluation of these films provided excellent anatomic detail which was increased in quality when the amplifier unit was used in the enlargement mode for a 5 inch field. (Figures 4, 5)

Figure 4
(Sample Cine Frame, lateral view - while playing - note soft tissue pad of soft palate occluding epipharynx)

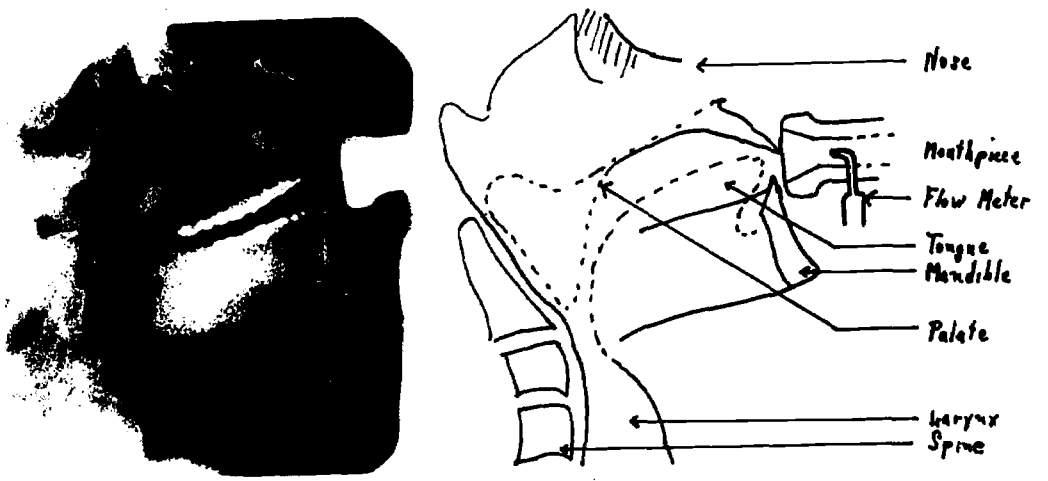
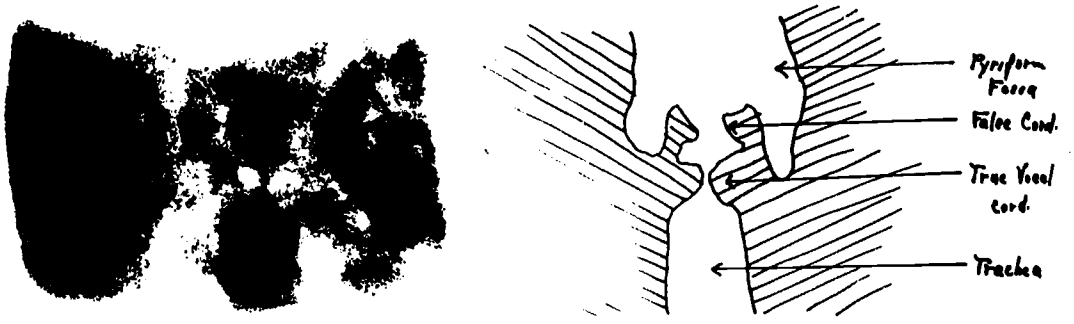


Figure 5
(Sample Cine frame AP Larynx)



Particular attention was paid to the safety factor of X-ray dosage exposure of the subjects. Therefore, X-ray dose calibration studies were performed prior to fluoroscopy and cine-filming. Representative dose measurements are shown in Table I.

TABLE I

X-Ray Dose Measurements

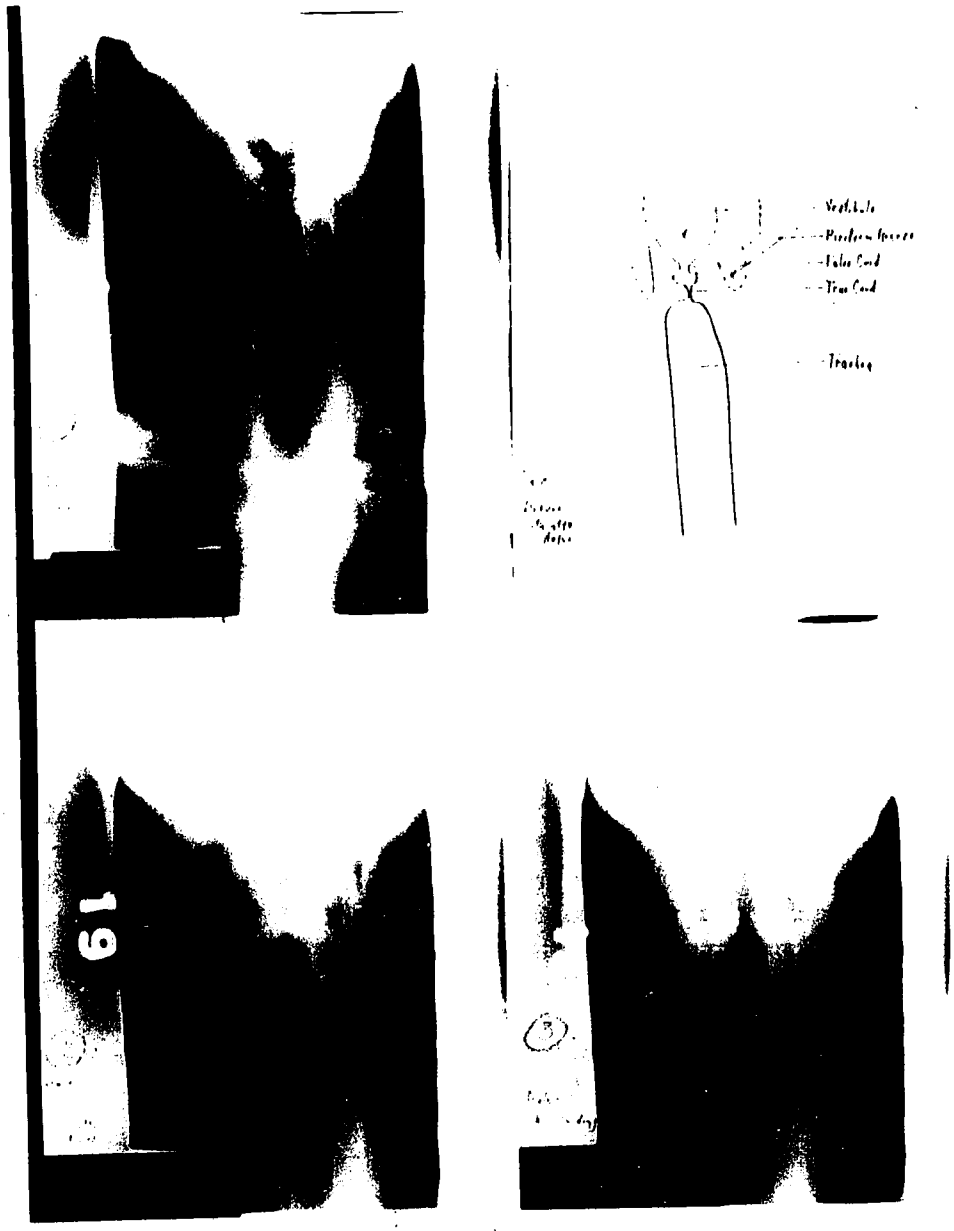
Setting		Yield
Fluoroscopic automatic setting 120 KV	1 inch aluminum phantom	0.75 MA-0.32 4 min.
Cine Recording 120 KV 25 frames per second	1 inch aluminum phantom	0.5 r/min.
Cine Recording 50 frames per second	1 inch aluminum	1 r/min.

f. Body section films of larynx during playing.

In addition to the cine X-ray studies, laminagraphic studies of the larynx in AP position were performed. For this dimension of the study the Philips polytome was adjusted in linear mode to the approximate center of the vocal cords. Exposures were made during the player's sounding of a note and during the rest interval between notes. These films produced excellent visualization of the true and false cord during sounding of notes and the intervals between notes. (Figure 6)

Figure 6
(Body section X-rays of Larynx)

1. Quiet Breathing
2. Scale between staccato notes
3. Scale, note sounding



II. Selection of Musical Pieces and Subjects

In the selection of musical pieces the project directors followed the proposed procedures of the project. After numerous trials with a number of etudes and scale exercises, Mrs. Hanson selected scales in F, D, and B-flat and two etudes which were performed both in staccato and legato by the subjects. The nature of the experiment did not demand that pieces of extensive length be selected, since previous experimentation with the physical parameters in trumpet playing had shown that these were neither numerous nor unique for different pieces of music. In addition the project directors were at all times conscious of the problem of X-ray exposure of the subjects. Practice sessions for beginning, intermediate and advanced players were conducted under the direction of Mrs. Hanson, who was also responsible for selection of subjects for the different recordings. Practice limit for all subjects was established at 10 minutes per day for two weeks before the actual recording. No special instruction or support was extended to any player. All players were volunteers and majors of the Music Department of Weber State College. All recording sessions were performed in the Department of Radiology of the McKay-Dee Hospital in Ogden, Utah.

RESULTS

Results from the experiment will be presented in two parts.

1. Analysis of individual subject's records.

2. Summary of trends.

1. Analysis of individual subject's recordings.

S1 Level: Advanced Player, student number W-18545A

Calibration:	Channel 1	Pharynx	X 0.37
Calibration:	Channel 2	Mouth	X 0.91

Run 1: Selected piece: Scale in F

Channel 1, Pharynx: Pressures vary from 11 mm to 23 mm mercury. Distinct pressure drop of 6-12 mm occurred between each note.

Channel 2, Mouth: Occluded

Channel 3, Air flow: Increased turbulence appeared with each sound, but no measurable flow rate was possible.

Cine: 25 frames per second AP. The true vocal cords approximate during the silent periods between each note and open to about 3 mm width at the sound period.

Run 2: Selected piece: Scale in F

Channel 1, Pharynx: Partially damped

Channel 2, Mouth: Occluded

Channel 3, Air flow: Occluded

Cine: 25 frames AP. The true cords approximate between each note. The aperture is approximately equal for each note during sounding of note, and varies from 2-3 mm.

Run 3: Legato and Staccato passages with D Scale

Channel 1, Pharynx: In all runs pressures up to 30 mm of mercury were recorded. Distinct pressure drop of 10-12 mm of mercury is observed on the record between each note.

Channel 2, Mouth: These pressures were frequently damped due to occlusion either by the tongue or strong saliva flow. Of interest however is the phenomenon of parallel pressure in this subject. During short intervals when pressures were recorded, they were approximately equal to the air pressures in the pharynx. Pressure drop between individual notes in staccato and legato scales was also approximately the same.

Cine: Cine frames parallel recordings of record. Technical failures of camera lead to only 60% true readings which can be used in profile.

Laminagraph Study

Laminagraphs of the larynx were recorded during scale playing. The unit was arranged in order to enable the shooting of a film during the interval between notes and during the playing of a note. Records display the true cords approximated during silence of the trumpet. Aperture of 3 mm in width appears when horn is sounded. No occlusion of false cords was observed.

S 2 Level: Advanced Player, student number W-18676A

Calibration: Channel 1 X 0.10) 10 mm deflection equals
Calibration: Channel 2 X 0.10) 10 mm mercury
Correction factor for both channels= 1.0

Run 1: Selected Piece: F Scale

Channels 1, 2 and 3 show extremely poor pressure recordings. Almost all channels are nearly completely occluded.

Cine: 25 frames per second AP. At the beginning of scale the larynx rises about 1 cm. The valleculae are observed to inflate, while the cords are brought into approximation. For each note the true cords open approximately at 3 mm range. At the end of the scale, the cords move to free breathing position, while the larynx descends.

Run 2 Selected piece: Legato F scale

Channel 1, Pharynx: Pressures are damped. Recording shows lower pressure than present in mouth. Presumably pressures are damped by saliva. Results from this run are therefore considered incorrect by investigators.

Channel 2, Mouth: Pressures register 38-70 mm of mercury, although slight dampening is again observed.

Channel 3, Air flow: Turbulence increased for each note played, quantitative measurement was not possible. Attempts to average mid-point of the turbulence evasive, did not yield valid results.

Cine: Good correlation is shown between this opening of the true cords and the time the note is sounding.

Run 3 Selected piece: F Scale Staccato

Channel 1, Pharynx: On both channels parallel pressures occur with peaks at 80 mm of mercury.

Channel 2, Mouth.

Cine: True cords open and close as in second run.

Run 4 Selected piece: F Scale Legato

Channel 1, Pharynx: Pressures damped by saliva with not enough accuracy for measurement.

Channel 2, Mouth:

Cine: Usual elevation followed by delicate opening and closing of the true cords. Proper analysis is made difficult due to the complexity of passage.

Run 5 Selected piece: Etude No. 1

Channel 1, Pharynx: Damped pressure due to saliva. Pressures recorded are below those registered for the mouth.

Channel 2, Mouth: Good recording without interference of dampening factors. Pressures vary from 55 to 68 mm of mercury with drops to 20-40 mm between each note.

Channel 3, Airflow: Peak turbulence occurs at the time of the sounding of each note.

Cine, Larynx AP: Good display of cord movement depicted in all frames.

Run 6 Selected piece: Etude Number 1

Channel 1 and 2, Larynx and Mouth: Both pressure channels are badly damped, recording is inaccurate.

Channel 3, Air flow: Good depiction of turbulent air flow, accurate measuring however impossible.

Cine: 50 frames, larynx AP. Adequate display of cord movement similar to other runs.

Run 7 Selected piece: Scale in D legato

Channel 1, Pharynx: damped, recording spotty.

Channel 2, Mouth: Probably partially damped but shows gradual pressure rise from 37 to 73 mm, as scale is played upward.

Cine: lateral view, 25 frames per second. The tongue flattens and then protrudes forward, almost to the upper incisor teeth. In the space between each note, it pushes the partially opaque mouth tube ahead of it. The motion is of the order of 1.5 cm. There is about 8 mm space between the posterior aspect of the tongue and the pharyngeal wall at all times. There is no significant motion in the back of the tongue.

Run 8 Selected piece: Scale in D staccato

Channel 1, Pharynx: damped, recording spotty.

Channel 2, Mouth: Pressures 33 to 81 mm of mercury with gradual rise toward upper end of scale.

Cine: Approximately same as above. There is tongue motion with each note.

Laminagraph studies

In quiet respiration --phonating--while playing a note and the space between two notes. The space between the note shows a slight chink between true cords.

S 3 Level: Advanced player, student number W-18861A (TM)

Calibration:	Channel 1	Pharynx	X 0.65
Calibration:	Channel	Mouth	X 0.625

Test 1: Selected piece: B Flat Scale Staccato

Channel 1, Pharynx: Pressures 19 to 25 mm of mercury gradually rising as the scale ascends. The upper pressure shows nearly a square wave for each note with a drop of about 20 mm of pressure between each note.

Channel 2, Air Flow: The pressure in the mouth is very nearly parallel to that in the pharynx.

Cine: No Cine taken on this test run.

Run 1: Selected piece: Scale B flat legato
Observing teacher notes: Scale is played "too separated"

Channel 1, Pharynx: Pressures 23 to 48 mm of mercury with drop of only 6 mm between each note.

Channel 2, Air Flow: The pressure ranges from 23 to 48 mm. Readings are slightly damped but show a definite pressure drop of about 6 mm between each note.

Cine: There is excellent correlation between the opening of the true vocal cords and the production of trumpet sound. When the cords are closed, the trumpet is silent. The larynx rises at the start of the passage and simultaneously closes the true cords.

Run 2: Selected piece: Scale B flat, legato

Channel 1, Pharynx: There is a gradual climb of pressures from 20 mm for the B flat to 51 mm for the octave above. The pressures decrease as the scale is played down.

Channel 2, Mouth: Slightly damped but with gradual peak to 51 mm of mercury.

Channels 3 and 4: Adequate air pressure recordings.

Cine: 25 frames per second AP larynx. There is well defined cord movement with opening up to 3 mm when each note is sounded. The larynx rises before the beginning of the passage, the valleculae inflate and the cords close. The first opening of the cords appears with the first note.

Run 3: Selected piece: Scale B flat, staccato

Channel 1, Pharynx: The typical stepped square wave from 30 mm of mercury to 52 mm of mercury with drops of 10 to 15 mm of mercury between each note.

Channel 2, Mouth: Essentially parallel to that of number 1.

Cine: 25 frames AP. The same as the others in the S3 runs. The laryngeal movement in Run 2 is similar to Run 3. Despite the fact that the latter is played staccato, the motion of the vocal cords appears the same.

Test Tracing Number 4: Selected piece: Whitney solo.

Channel 1, Pharynx: Sustained pressures 25 to 30 mm of mercury for 7 seconds. No pressure drop between individual notes is to be seen.

Channel 2, Mouth: The pressures parallel those above without drop of pressure at any point.

Cine: No Cine taken.

Run 4: Selected piece: Whitney solo, Legato passage

Channel 1, Pharynx: Sustained pressure about 32 mm of mercury for 8 seconds.

Channel 2, Mouth: Damped, but pressure rise to 29 mm mercury.

Cine: Good display of vocal cord movement which correlates with the sound production.

Laminagraphs

Laminagraphs were taken during scale playing. The view made during the rest period is particularly good, showing the inflated ventricles and false cords approximated.

S 4 Level: Intermediate player, Student number W-18864A

Calibration:	Channel 1	Pharynx X 0.77
Calibration:	Channel 2	Mouth X 0.77

Test 1: Selected piece: B Scale legato

Channel 1, Pharynx: Excellent tracing 33 to 63 mm mercury. The pressure drops 19 mm between each note. Thus the residual pressure is 14 to 44 mm of mercury when the trumpet is silent.

Channel 2, Mouth: There is intermittent damping but the pressures are approximately parallel to the pressures observed in channel 1.

Cine: No cine because of difficulties with apparatus.

Run 1: Selected piece: B Scale legato

Channel 1, Pharynx: Fair record, 35 to 67 mm mercury.

Channel 2, Mouth: Damped but roughly parallel.

Channel 3, Air flow: Turbulent

Cine: The movement of the larynx in this player is slightly different from the previous players. The false cords are seen to approximate and touch at the same time as there is approximation of the true cords. There is good correlation between sound and open larynx.

Run 2: Same selected piece of music: Scale staccato

Channel 1, Pharynx: Pressures range 35 to 68 mm mercury. There are pressure drops of 27 mm between each note.

Channel 2, Mouth: Good tracing on records which parallel channel 1.

Channel 3, Air flow: Turbulence only. The turbulence increases when the note is played but there is constantly some disturbance in this channel.

Cine: The appearance is the same as in number 1. The laryngeal chink opens to 2 to 3 mm between each note. There is movement of both true and false cords into approximation during each rest period.

Run 3: Same selected piece of music: The legato passage

Channel 1, Pharynx: Partly damped.

Channel 2, Mouth: Totally occluded.

Cine: Cord movement displayed similar to previous runs.

Run 4: Selected piece of music: Etude Number 1

Channel 1, Pharynx: Excellent tracing, pressures vary from 31 to 51 mm mercury. Pressure drops of 27 mm are observed between each note.

Channel 2, Mouth: Damped but roughly parallel to number 1.

Cine: Good record true and false cords come together.

Run 5: Selected piece of music: Grand Russian

Channel 1, Pharynx: Adequate recordings with pressure variations from 40 to 50 mm mercury.

Channel 2, Mouth: Damped, roughly parallel.

Channel 3, Air flow: The greatest turbulence seen yet.

Cine: Run is good and again the true and false cords are approximating.

Run 6: Same selected piece of music: Scale legato

Channels 1, 2: Adequate usual pressure variations.

Cine: Lateral view. The tongue flattens and then goes through a 2 to 3 cm forward excursion between each note. The back of the tongue leaves at least 4 mm space between its wall and the pharynx.

Run 7: Same selected piece of music: Scale legato

Channel 1, Pharynx: Partially damped

Channel 2, Mouth: Totally damped

Cine: Lateral -- good display. The tongue moves the mouth tube between each note.

Run 8: Selected piece: Scale staccato

Channel 1, Pharynx: Good record. 32 to 73 mm of mercury with distinct drops of 27 mm between each note.

Channel 2, Mouth: Good part of the way and then damped. It parallels number 1.

Cine: Lateral view. Good depiction of tongue movement.

Laminagraphs

The film showing the rest between the two notes shows true and false cords together. It is distinctly different from the appearance of the cords in the view made while phonating.

In the advanced two players, the cords approximated to present much the same appearance as when phonating. It would seem that when true and false cords are both brought together, that the mechanism must be somewhat more clumsy than the more delicate motion possible with the true cord alone.

S5 Level: Beginning player, Student Number W-21236

Calibration:	Channel 1	Pharynx X 0.71
Calibration:	Channel 2	Mouth X 1.0

Run 1: Selected piece: B Scale legato

Channels 1, 2, 3: No trace. (With the beginning players, it was felt that Cine record should be made without the disturbance of the pharyngeal and mouth catheters in place. Runs 8 and upward are made with the catheters in place and pressures made).

Cine: The cords move slightly but do not seem to touch. In the open position, the chink seems narrower than with the experienced player.

Run 2: Selected piece: Scale staccato (Failed to complete).

Cine: Cords are seen to move but do not touch.

Run 3: Selected piece: Scale staccato (Failed to complete).

Cine: As above. The laryngeal chink is very narrow at all times and cord motion is minimal.

Run 4: Selected piece: Scale legato.

Cine: Lateral view. The tongue movement is much more prominent than with the experienced player, the excursion is upward of 3 cm with the tip of the tongue rising upward and behind the incisors for each note.

Run 5: Selected piece: Scale staccato

Cine: Lateral. The tongue movement is accentuated, the back of the tongue seems to be somewhat forward, leaving 1 cm plus between the tongue and the pharyngeal wall.

Run 6: Selected piece: Scale legato

Cine: Lateral. Accentuated tongue movement throughout.

Run 7: Selected piece: Scale staccato.

Cine: As above. Tongue motion is exaggerated.

Run 8: Selected piece: Scale legato.

Channel 1, Pharynx: There is gradual pressure rise from 13 to 38 mm of mercury but no separation between successive notes is recognizable.

Channel 2, Mouth: Damped.

Cine: Cord movement is quite indistinct. Just before the passage begins the larynx rises and the cords close partially to about 1 to 2 mm chink, but do not seem to move purposefully during the playing of the passage.

Run 9: Selected piece: Scale staccato

Channel 1, Pharynx: Good record. Gradual pressure rise from 14 to 40 mm but there is no pressure drop between individual notes.

Channel 2, Mouth: Damped.

Channel 3, Air flow: Turbulent

Channel 4, Sound: Where there is good separation of notes, there has been repetition of several notes of the scale.

Cine: AP. The cords do not come together but remain at about 1 to 2 mm separation throughout the playing of the entire passage.

Run 10: Selected piece: Scale legato

Channel 1, Pharynx: There is barely recognizable separation of some of the notes. Pressure rise from 14 to 36 mm and return again.

Channel 2, Mouth: Roughly parallel.

Channel 3, Air flow: Considerable turbulence but cannot even recognize individual notes.

Cine: Lateral. Much tongue movement with the tongue carried far forward and on to the upper incisors at the space between each note.

Run 11: Selected piece: Scale slow staccato (not completed).

Channel 1, Pharynx: Constant pressure rise from 14 to 40 mm. No pressure drop can be seen between the notes.

Channel 2, Mouth: Somewhat damped but it parallels number 1.

Cine: Lateral view. Marked tongue motion with a large open space behind the tongue and the sharp protrusion of the tongue forward between each note.

S 6: Level: Beginning player, Student number W-21327A

Calibration:	Channel 1	Pharynx X 0.71
Calibration:	Channel 2	Mouth X 1.0

Runs 1 through 5 are made without pressure tracings. The pressure tracing are approximately the same as in the subsequent runs where Cine and pressure were made together.

Run 6: Selected Piece: Scale legato

Channel 1, Pharynx: Pressure rises from 20 to 36 mm of mercury but there is no drop between the individual notes.

Channel 2, Mouth: Pressure changes up to 36 mm but there is 20 mm drop between each note. I suspect that the tongue protruding forward occludes the mouth tube between each note.

Cine: AP. The cords move slightly but there is a constant chink of 1 to 2 mm both during and between notes.

Run 7: Selected piece: Scale staccato

Channel 1, Pharynx: 22 to 35 mm of mercury with irregular pressure jumps and interruptions.

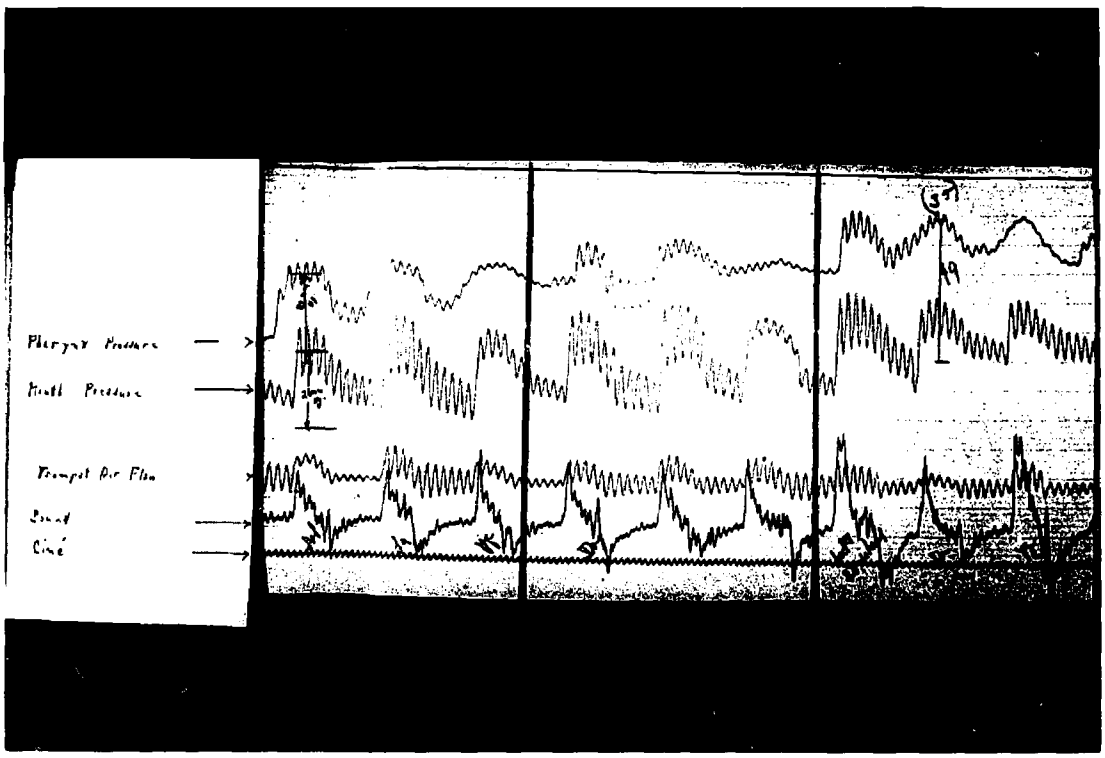
Channel 2, Mouth: Pressures are roughly parallel with above but there is clear-cut pressure drop between each note.

Channel 3, Air flow: Recognizable air flow during each note.

Cine: The cords open and close here from 0 to 2 mm. I do not understand why the cords seem to open and close in this particular passage when they did not do so in the others.

(See figure 7)

Figure 7
(Typical pressure tracing
Run 7 beginning player)



Run 8: Selected piece: Scale legato

Channel 1, Pharynx: Pressures up to 38 mm of mercury but there is no separation or pressure drop.

Channel 2, Mouth: Pressures up to 36 mm with distinct pressure drop between each note.

Cine: Lateral. There is very prominent tongue movement. It is quite reminiscent of what happens to a woodpeckers bill.

Run 9: Selected piece: Scale staccato

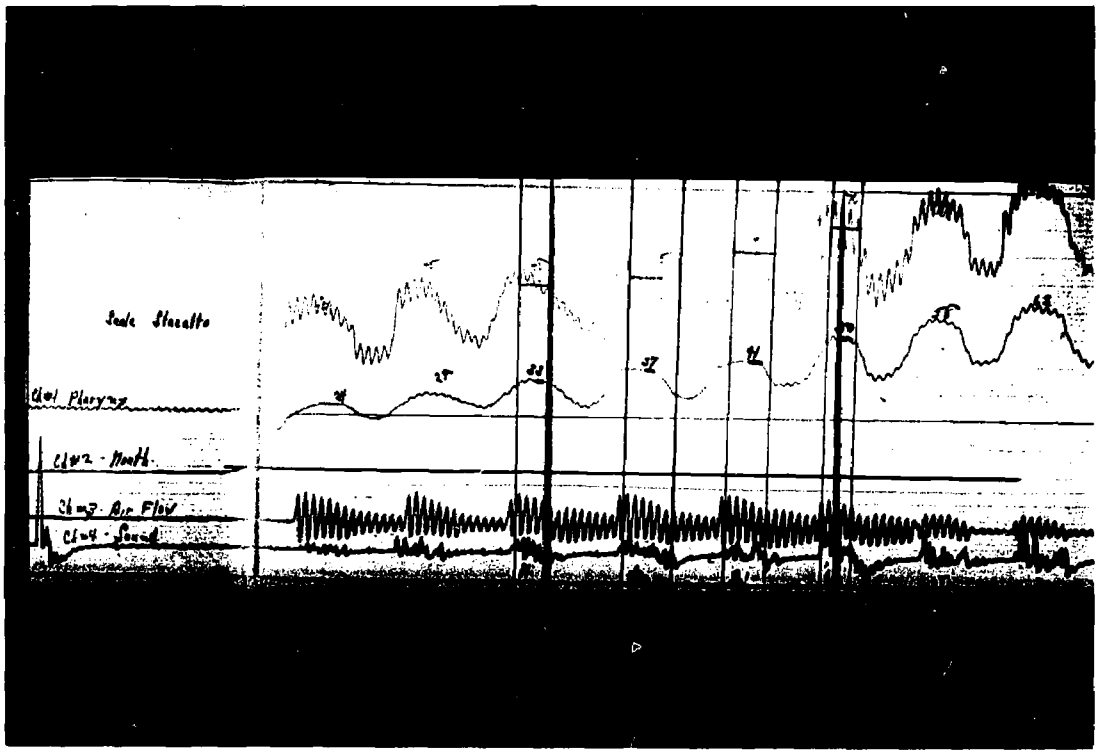
Channel 1, Pharynx: 14 to 43 mm of mercury with 10 mm drop on some of the spaces between notes. This recording looks more like the recording of the advanced player than any other.

Channel 2, Mouth: 16 to 45 mm pressure with 20 mm drop between notes.

Cine: Marked forward and backward movement of the tongue with each note. Far more tongue movement than with any of the advanced players.

S 7: Level: Advanced player, Student Number X-3024 A

Figure 8
(Typical Pressure tracing
Advanced player - staccato scale)



Calibration: Channel 1 11 mm deflection = 10 mm Hg.
Calibration: Channel 2 11 mm deflection = 10 mm Hg.

In this series, the connecting tubes of the pressure Channels 1, 2 and the air flow channel 3 were water filled (rather than air filled as in previous subjects). However, no significant differences in quality of recording resulted. The turbulence, particularly of channel 3, which has plagued us throughout the experiments, was recorded exactly as before.

Run 1: Selected piece: Scale staccato

Channel 1, Pharynx: Partially damped after five notes.

Channel 2, Mouth: Partially damped throughout.

Channel 3, air flow: Turbulent - Not even adequate to see separation between individual notes of scale.

Channel 4: Sound channel is good throughout.

Channel 5: Cine frame correlation - no record, (an open wire at the x-ray control).

Cine: AP. Good display of true cord motion -- the false cords move but do not touch.

Run 2: Selected piece: Scale staccato

Channel 1, Pharynx: Good record on the way up -- then damped. Pharynx pressure low point between notes rises from 4 mm Hg to 60 mm Hg. Pressure during sounding of note rises 45 to 60 mm above the low point while the note sounds. The pressure rise from the low point of the curve begins about 100 m Sec before note sounds -- is held at high point during sound -- and drops to next low point in 110 m Sec.

Peak Pressures Do = 40 mm Hg.
Sol - 76 mm Hg.
Do = ca 110 m + (off scale)

Channel 2, Mouth: Damped

Cine: Depicts the usual motion of true cords.

Run 3: [illegible]

Channel [illegible]: [illegible]

Cine: [illegible] of true cords.

Run 4: [illegible]

Channel 1, Pharynx: Good record. Peak pressure 43 mm to 110 mm Hg. The pressure rise for each note starts 100 to 110 m Sec before the actual sound is heard.

Channel 2, Mouth: Good record. [illegible] 30 mm to 55 mm Hg -- lower than in the pharynx. Here too, the pressure rise begins about 100 m Sec before the note.

Cine: AP, Larynx. Good cord movement.

Run 5: Selected piece: Scale legato

Channel 1, 2: Damped.

Cine: AP larynx. Cord movement is depicted. The true cords approximate between each note but this movement is slower than in the other scales.

Run 6: Selected piece: Scale staccato

This is the best pressure record of this series.

Channel 1, Pharynx: Peak pressures from ~~40 mm Hg~~ to 88 mm Hg. In the intervals between notes, the pressures drop 20 to 50 mm.

Channel 2, Mouth: Peak pressures range from 24 mm to 63 mm Hg. Drops of 20 mm Hg occur between each note.

Channels 3, 4: Adequate

Cine: Lateral of mouth, tongue, larynx -- interrupted series -- little tongue movement depicted.

Run 7: Selected piece: Scale legato

Channel 1, Pharynx: Partially damped. Pressures of 24 mm to 85 mm Hg are recorded.

Channel 2, Mouth: Partially damped. Pressures up to 60 mm Hg are recorded -- pressure drops between notes are not seen.

Cine: Lateral. Good record with minimal tongue motion.

Run 8: Selected piece: Scale staccato

Channel 1, Pharynx: Good record but pharynx goes off scale. Most of these pressure peaks round off rather than plateau as in some of the other runs. Pressure drops of 25 to 30 mm Hg are seen between each note.

Channel 2, Mouth: Pressure from 31 to 76 mm Hg with drops of 20 to 40 mm between each note.

Cine: AP larynx reveals approximations of true cords between each note.

Run 9: Selected piece: Scale legato

Channel 1, Pharynx: Pressure shows gradual rise from ca 27 to 60 mm Hg and returns.

Channel 2, Mouth: Pressure rises from 24 to 60 mm Hg and returns. No pressure drops between notes in either 1 or 2.

Cine: AP Larynx. Little movement of cords.

Run 10: Selected piece: Scale staccato

Channel 1, Pharynx: Adequate depiction of pressure with pressure drop between each note.

Channel 2, Mouth: Pressures of 28 to 70 mm with 20 to 40 mm drop between each note.

Cine: Lateral. Tongue movements were the most prominent of this series. The tip of the tongue rises behind the upper incisors between each note.

Run 11: Selected piece: Scale legato

Channel 1, Pharynx: Gradual pressure rise and fall without any pressure drops between notes.

Channel 2, Mouth: Gradual pressure rise to 70 mm Hg and returns. No separation between notes.

Cine: Lateral. Tongue rises between notes but does not occlude at teeth.

Run 12: Selected piece: Short passage of staccato notes.

Channel 1, Pharynx: Partially damped.

Channel 2, Mouth: Clear separation between each note with drops of 20 to 30 mm Hg. Pressures vary with pitch up to 45 mm Hg.

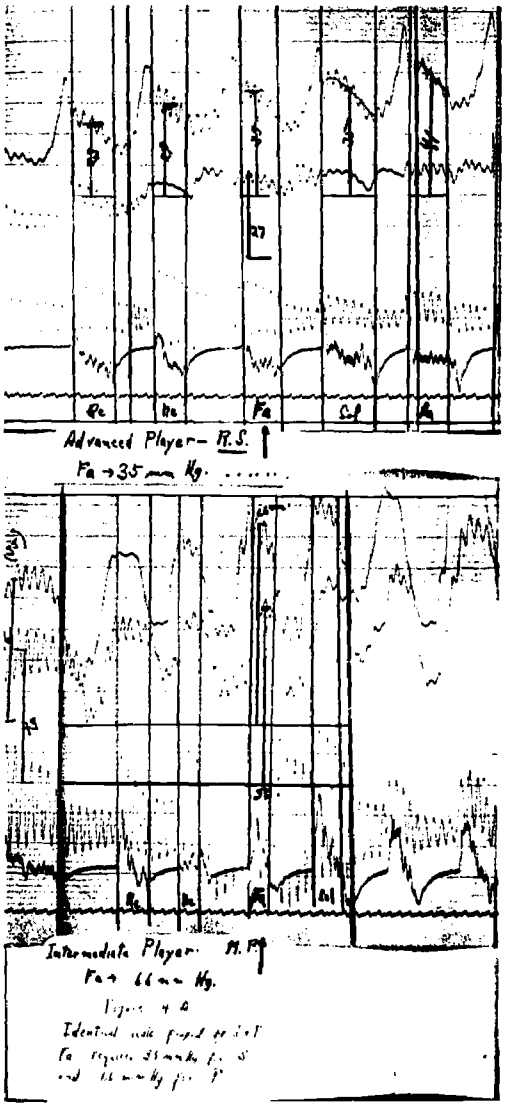
Cine: AP. Good movement of true cords is depicted.

This player was characterized by several inconsistencies of performance. Peak pressure for a given note varied on successive runs of the same scale. Frequently, the peak pressure for a given note was not held as a plateau during the playing of a given note but rather rounded off while holding a single pitch. The records seem to support the conclusion that the larynx, tongue and lip muscles can all take part in starting and stopping the trumpet sound. They also seem to support the idea that the better player uses the tongue less than the beginning player. The preferred method would seem to be control by larynx true cords and finally by the lip muscles.

SUMMARY OF TRENDS

a. Recordings of pressure in the hypopharynx and the anterior part of the mouth were made in advanced, intermediate and beginning players. Distinct differences were displayed between the three groups in the control of pressure constancy. The beginning player does not portray precise pressure control, as evidenced by the fluctuating recordings. Advanced and intermediate players showed distinct pressure drops in the pharynx region between each note played. Beginning players did not drop pharyngeal air pressure between notes. (Figure 9)

Figure 9
(Pressure tracings of two different trumpeters)



The pressures used for playing simple scales seemed to vary from player to player. Absolute pressures ranged from 16 mm to 36 mm on the lower end for the production of a clear sounding scale, while another player at the upper range on the scale used pressures of 36 to 81 mm of mercury. It is of interest to note, that there was no correlation between absolute pressures and experience level of players. A second negative correlation existed between volume of produced sound and air pressure used. (Figure 10)

Figure 10
(Advanced player - scale staccato)

b. Great difficulty was experienced in the investigator's attempts to produce precise recordings of mouth pressure during trumpet playing. On the ten records which turned out to be adequate for this investigation, almost identical air pressures were found between the mouth and pharynx region. An exception to this finding occurred in the different player levels during the interval between notes. In intermediate and advanced players the pressure drop in the mouth equated approximately the pressure drop in the pharynx. In contrast hereto the beginning players showed distinct pressure drops in the mouth region, which were not accompanied by parallel drops in the pharynx region. This phenomenon is probably caused by the beginning player's tendency to protrude the tongue to a point where occlusion of the air stream and the mouth pressure tube followed as a natural consequence regardless of level of playing.

Precise correlation existed between the pressure variations of both mouth and pharynx regions and the sound production of the trumpet. When the pressure in the pharynx and mouth dropped, the trumpet was silent. When pressures rose, notes were produced.

c. The Cine X-ray records and the laminagraphic X-ray views of the laryngeal region correlated remarkably well with pressure and sound variations in the different levels of player competency. In the experienced players the true vocal cords were seen to approximate while the trumpet was silent and were opened 2-3 mm during sound production with the trumpet. Tongue movement was minimal. It averaged from 1 to 1.5 cm and with exception did not occlude the air space behind the incisors.

In contrast to the mouth correlation between these factors in intermediate and advanced players, the laryngeal movement in the beginning player was usually deficient and unpredictable. Frequently the beginning player interrupted the air flow in both laryngeal and mouth region. The latter interruption was caused by pushing the tongue against the upper incisors. The pressure of the tongue against the incisors in the beginning player can be compared to the head movements of a woodpecker. In contrast to the rapid and rather uncontrolled tongue movement of the beginning player, tongue movement becomes less pronounced and much more voluntarily directed by the more experienced player.

CONCLUSIONS AND RECOMMENDATIONS

The analysis of graphic profiles from beginning, intermediate, and advanced players showed significant differences and some surprising similarities in the following dimensions:

a. Pressure control

The constancy of recorded pressure drops in advanced and intermediate players in the pharynx region in contrast to the apparent capacity was the first significant result of this study.

As a recommendation for the teaching of trumpet playing, this finding suggests that particular attention be paid to achieve this control system in beginning players. Pharyngeal air pressure drops between notes seems to be a significant mark of intermediate and advanced technique of trumpet playing.

b. Absolute pressures

Variation in pressures used for playing scales depended on the individual player and did not correlate with the level of achievement.

This finding suggests to the teacher of trumpet playing that less effort needs to be extended by the beginning player to the achievement of high pressure volume, since precision of playing and pressure volume were not related.

c. Sound volume

It was interesting to note that the investigation could not establish a positive correlation between the volume of produced sound in the subjects and the air pressure used. Although this finding was incidental and the number of subjects used was relatively small (10), the trend observed suggests to the teacher of trumpet playing that increase in volume of air pressure will not necessarily lead to increase of volume in the production of sound. Yet, in the experience of Hanson (one of the principal investigators) all too often substantial amounts of didactic efforts are directed by teachers to exercise controlling mechanisms of sound through air pressure increase rather than through achievement of precise

pressure variations and correlations between vocal cord (laryngeal movement) and mouth region.

d. The importance of the vocal cord

From the analysis of profiles in this study, the investigators feel safe to conclude control movements of the true vocal cord are the most important mechanisms for the production of sound and sound interruption in trumpet playing. As evidenced in the X-rays, intermediate and advanced players approximated the true vocal cords while the trumpet was silent and were seen to open these cords from 2-3 mm whenever a sound was produced. In contrast hereto the beginning player produced deficient and unpredictable laryngeal movement. Tongue pressure against the upper incisors rather than steady laryngeal opening and closing characterize the records of the beginning player.

Constant air flow between laryngeal and mouth region controlled by the valve system of the true vocal cord seems thus to produce the basic difference in the levels of artistic activity. It is only the true vocal cord which has sufficient delicacy of movement which can guarantee desired quality of sound production or needed sound interruption.

The verified knowledge of these anatomical and physiological features of this study can in the opinion of the investigators contribute substantially to a sounder methodological program in the teaching of trumpet playing.